

Top quark pair production cross section measurements at CDF & D0

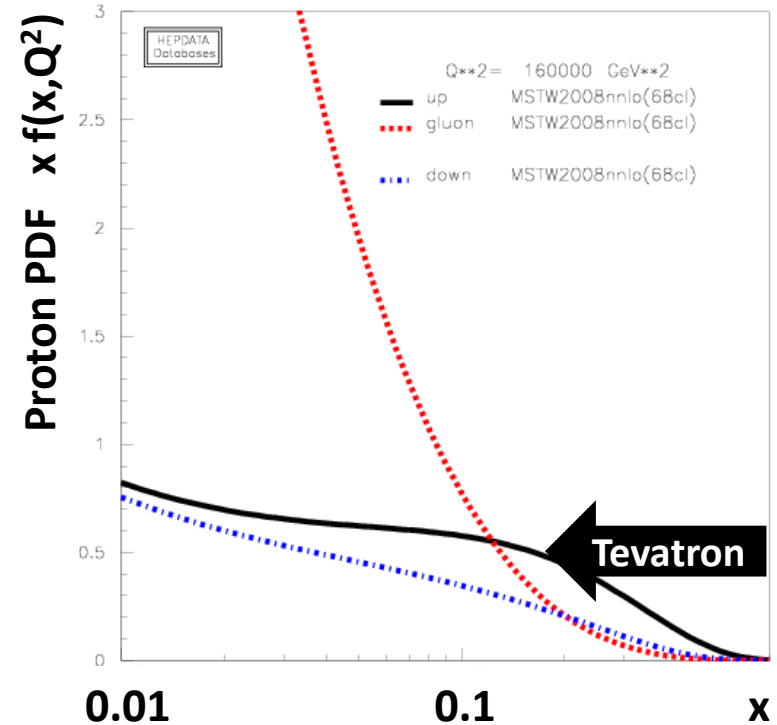
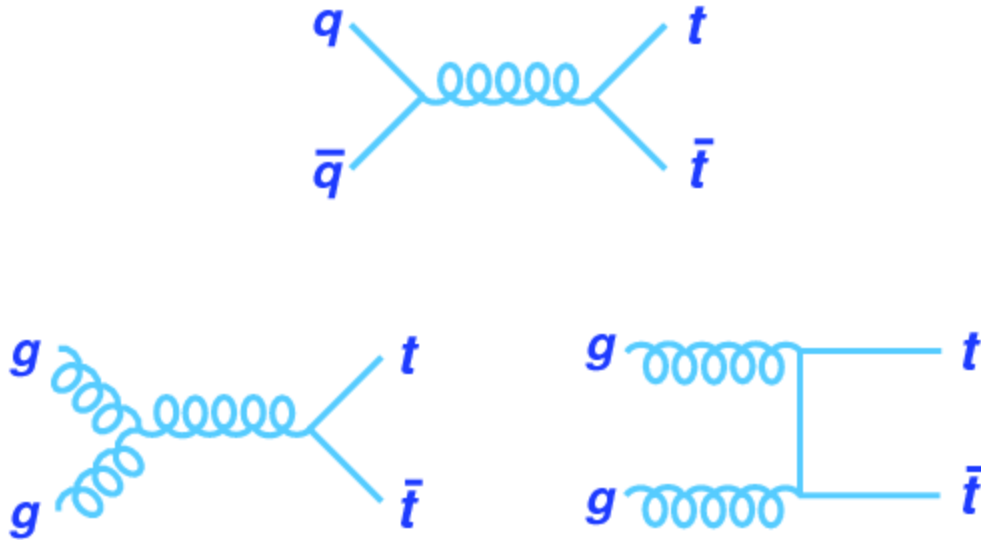


April 9 2015

Top at Twenty
Evelyn Thomson

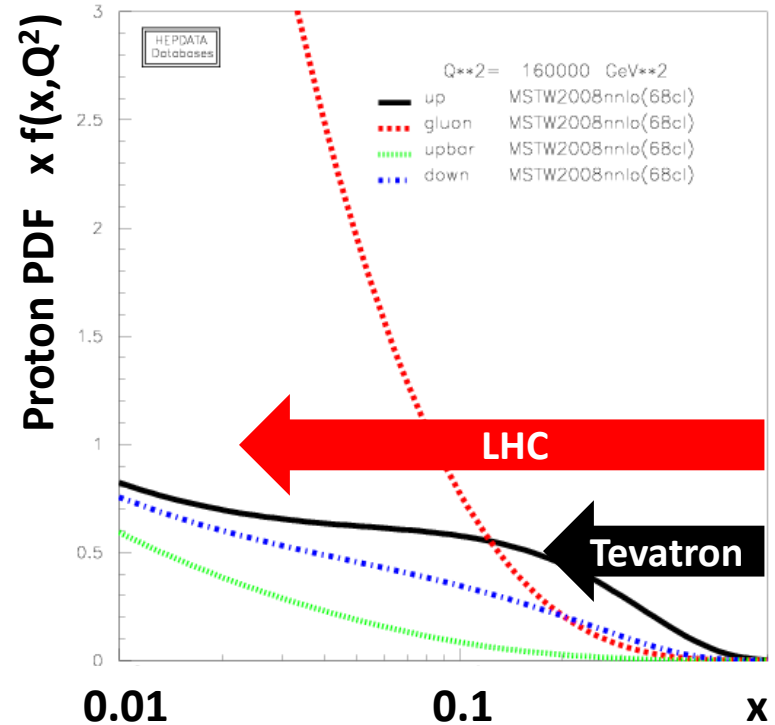
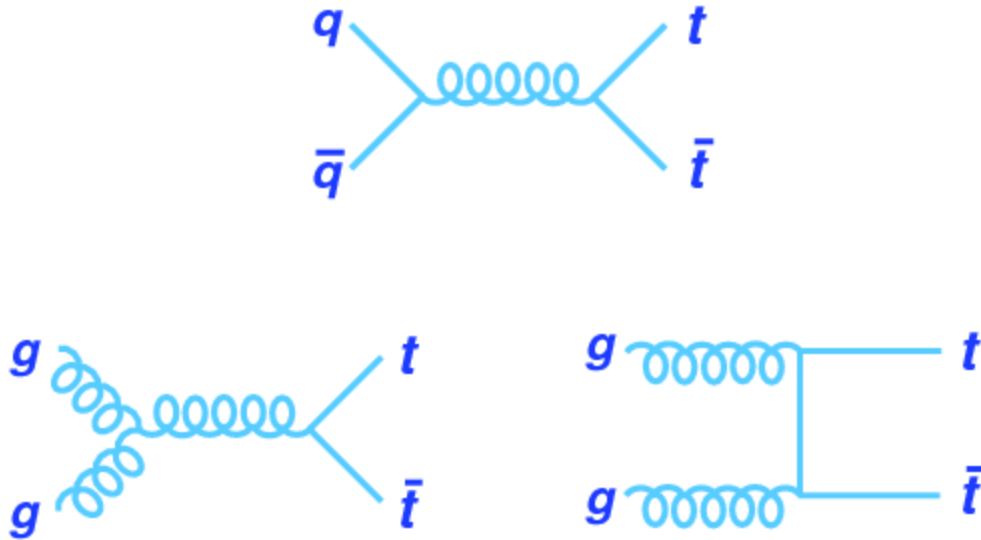
University of Pennsylvania

Strong Pair Production



Tevatron collides 980 GeV beams of protons and anti-protons:
 minimum $x=0.18$ so quark anti-quark annihilation dominates [85%]

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LHC collides 4 TeV (6.5 TeV) beams of protons and protons

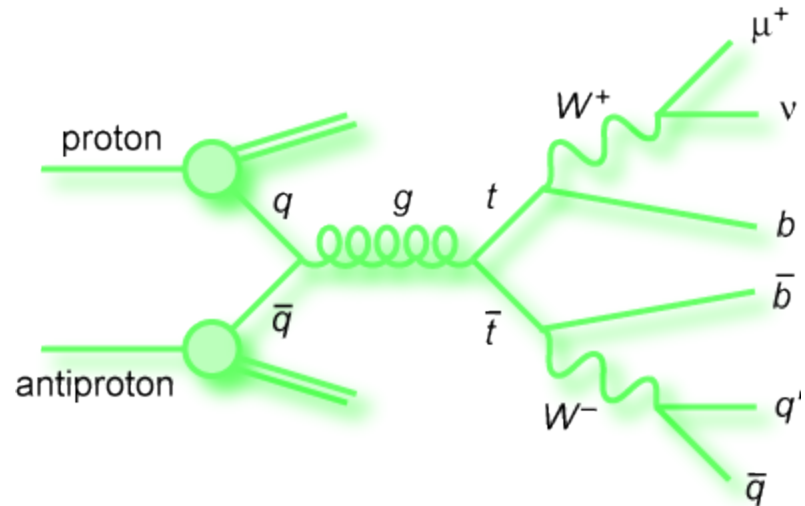
minimum $x=0.043$ (0.027), so gluon fusion dominates [above 80%]

Three experimental final states

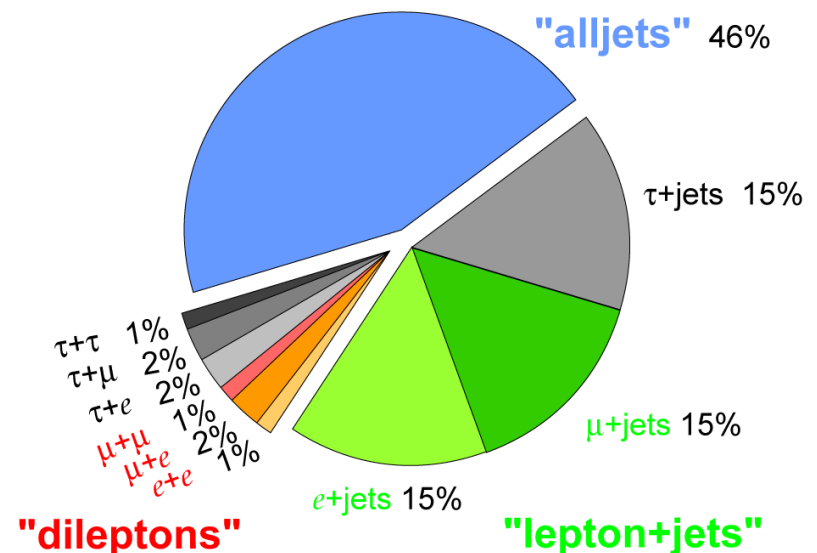
Common feature is two b-jets
from weak decays $t \rightarrow Wb$

Subsequent decay of W^+W^-
bosons gives three final states

4% dilepton
30% single lepton+jets
46% all jets



Top Pair Branching Fractions



Inclusive cross section in Run II

5% precision by combining six measurements from CDF & D0

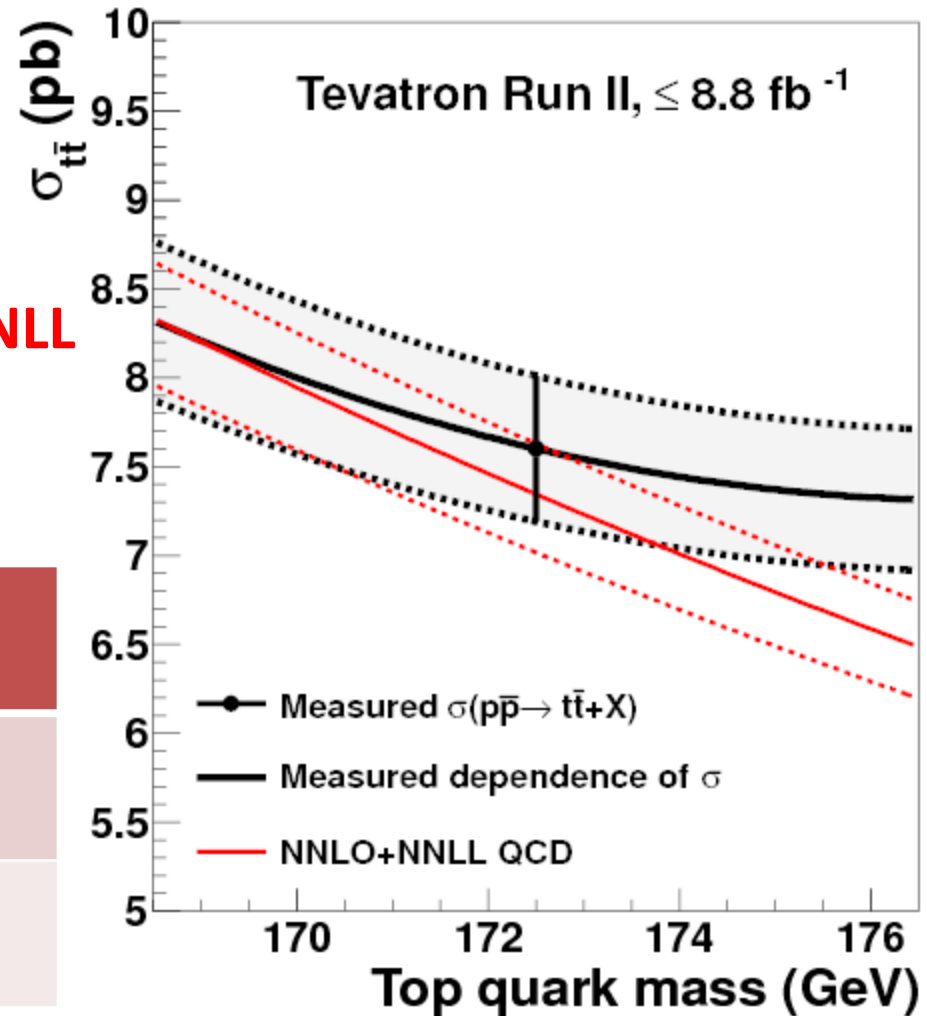
$7.60 \pm 0.41 \text{ pb}$

CDF+D0, PRD 89, 072001 (2014)

4% precision from theory NNLO+NNLL

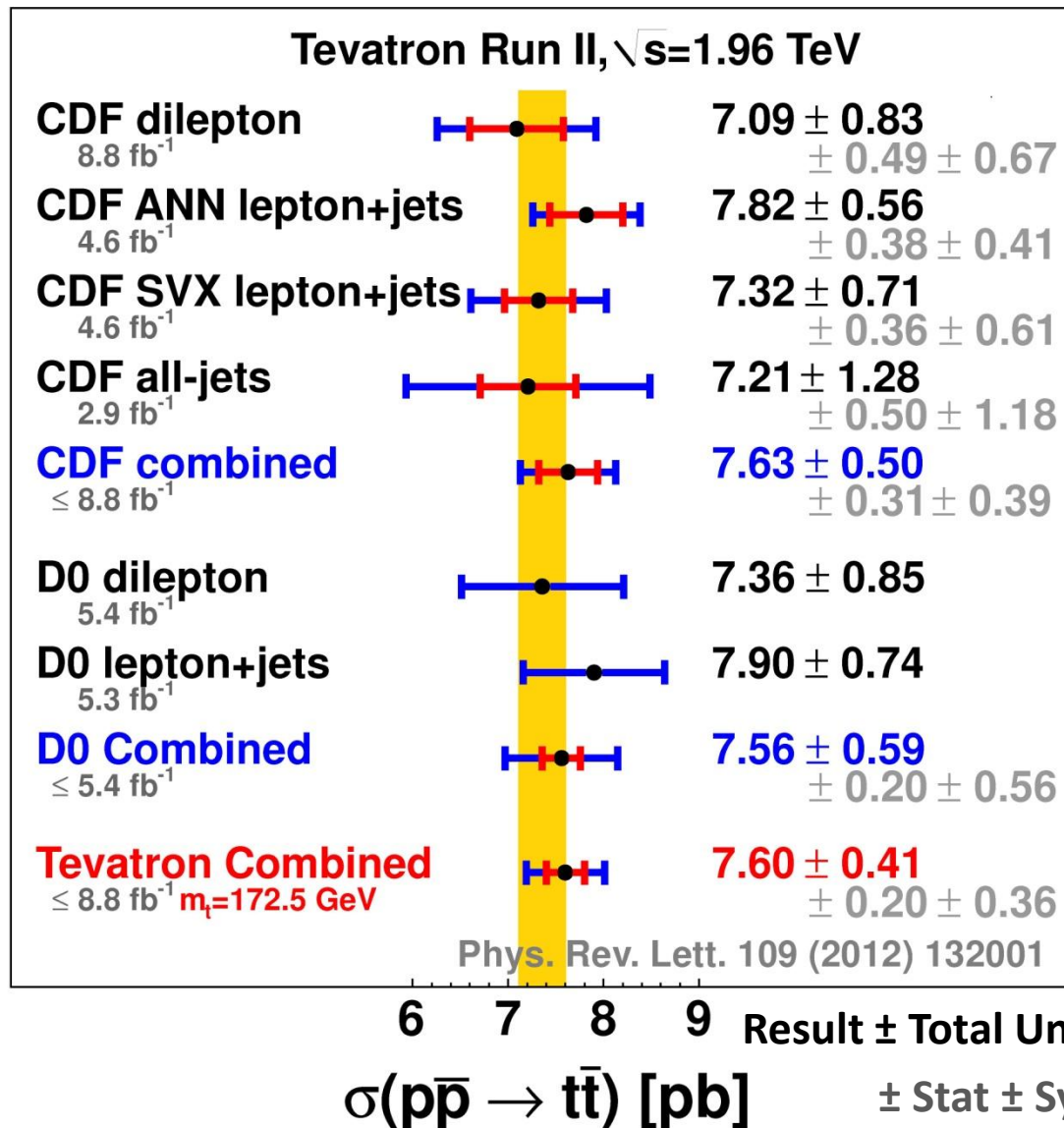
Barnreuther, Czakon & Mitov

PRL 109, 132001 (2012)



Prediction top++ $m_{\text{top}} = 172.5 \text{ GeV}$	σ (pb)	Δ Scale (pb)	Δ PDF (pb)
NLO+NLL	7.09	+0.28 -0.51	+0.19 -0.13
NNLO+NNLL	7.35	+0.11 -0.21	+0.17 -0.12

Inclusive cross section in Run II



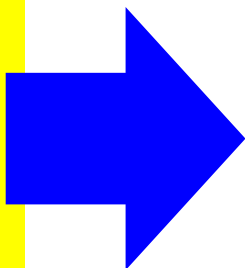
Good agreement
between final states

Combine with Best
Linear Unbiased
Estimate (BLUE)
with correlations of
systematics
between results

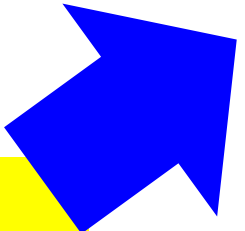
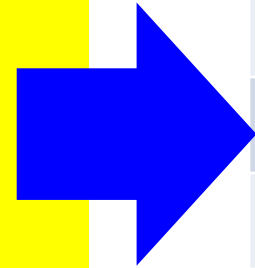
5% precision *CDF+D0*,
PRD 89, 072001
(2014)

Uncertainties (pb)

D0 optimized technique to reduce statistical uncertainty



CDF reduced 6% luminosity uncertainty to 2% by normalization to Z cross section

Uncertainty (pb)	CDF	D0	Tevatron
Statistics	0.31	0.20	0.20
All systematics	0.39	0.56	0.36
Signal model *	0.21	0.13	0.18
Luminosity (inel)*	0.05	0.30	0.15
Luminosity (det)	0.06	0.35	0.14
Detector model	0.17	0.22	0.13
Jet model	0.21	0.11	0.13
Bkg theory *	0.10	0.08	0.10
Z normalization	0.13	N/A	0.08
Bkg data	0.08	0.06	0.05
Method	0.01	0.07	0.03

D0 Lepton+Jets

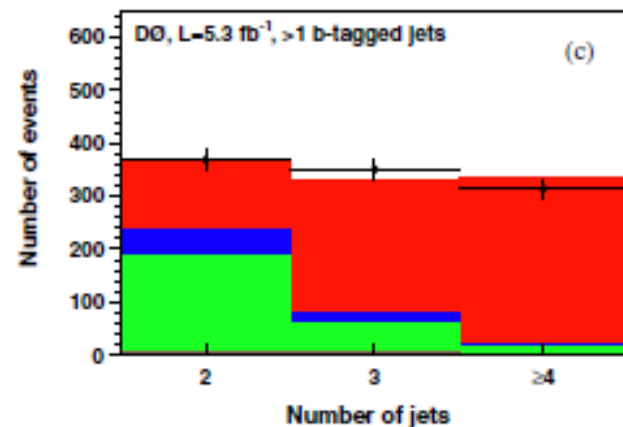
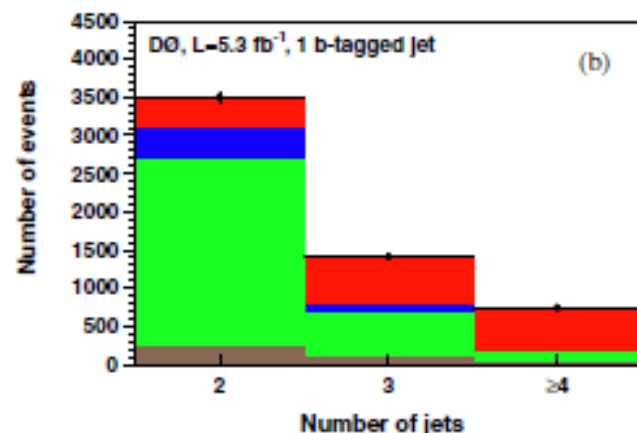
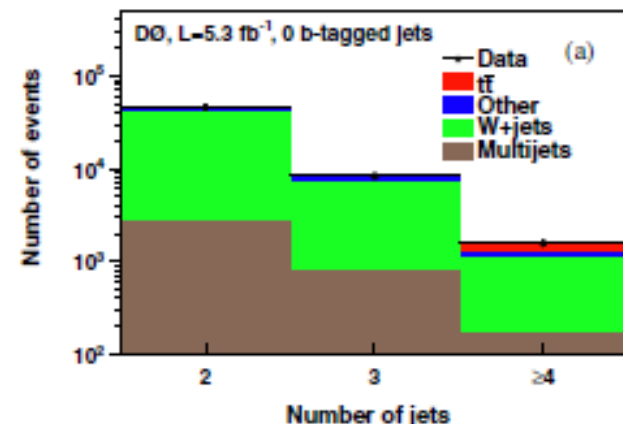
Classify by number of jets and b-tags

- If dominated by top, then fit number of selected events with estimate of small W+HF backgrounds
- If dominated by background, then fit discriminant based on kinematics

Excellent statistical sensitivity, but more sources of systematic uncertainty with kinematics, b-tagging and W+HF

Can use W+2 jets to fit W+HF fraction (small difference between PRD and PLB)

$7.90 \pm 0.74 \text{ pb combined } 5300 \text{ pb}^{-1}$
PRD 84, 012008 & PLB 704, 403 (2011)



D0 Lepton+Jets

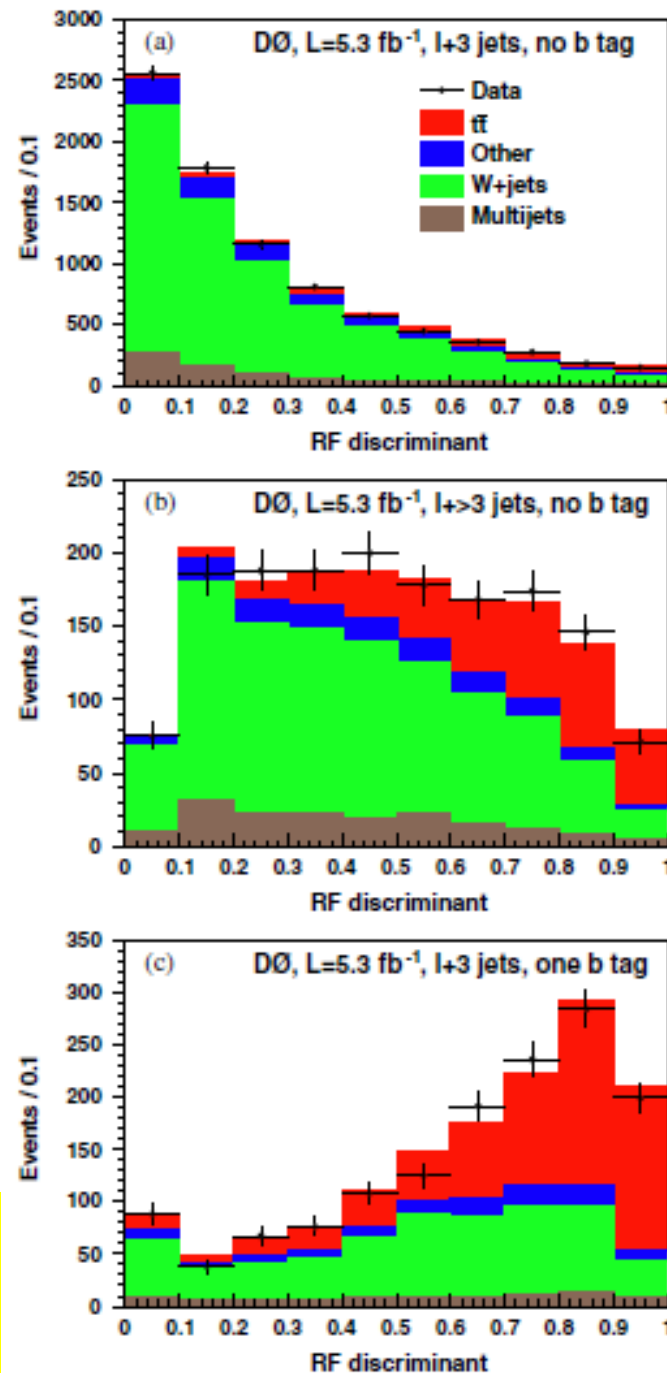
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CDF Lepton+Jets

Reduce luminosity uncertainty
from 6% to 2% for first time

- Measure ratio of $t\bar{t}$ and Z/γ^*
- Normalize to Z/γ^* theory

Fit $t\bar{t}$ and W +jets from a
discriminant with kinematics

$$7.82 \pm 0.56 \text{ pb} \quad 4600 \text{ pb}^{-1}$$

Reduce W +jets background with
b-tagging, fit number of events

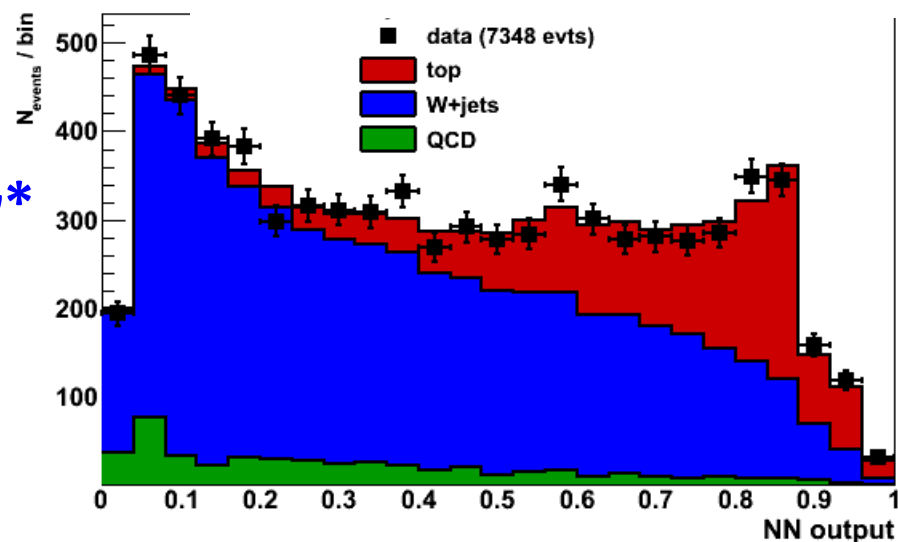
$$7.32 \pm 0.71 \text{ pb} \quad 4300 \text{ pb}^{-1}$$

Only 30% statistical correlation
since different information used

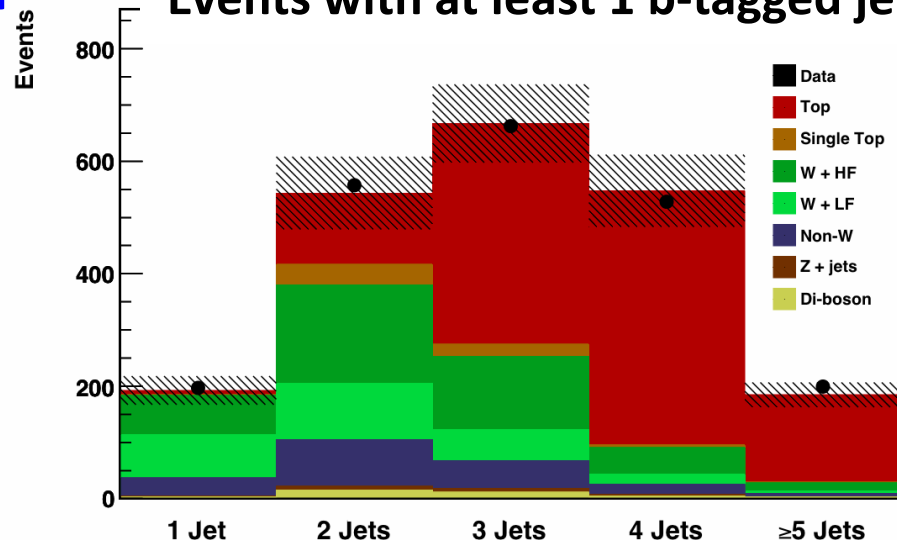
$$7.70 \pm 0.52 \text{ pb combined}$$

CDF PRL 105, 012001 (2010)

Discriminant for at least 3 jets



Events with at least 1 b-tagged jet

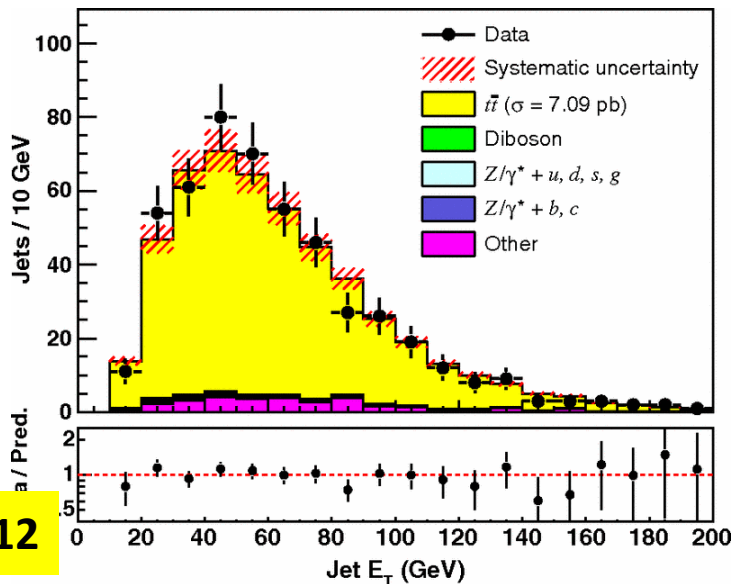


Dilepton & All-jets

$7.09 \pm 0.83 \text{ pb}$ 8800 pb^{-1}
CDF PRD 88, 091103(R) (2013)

Dilepton

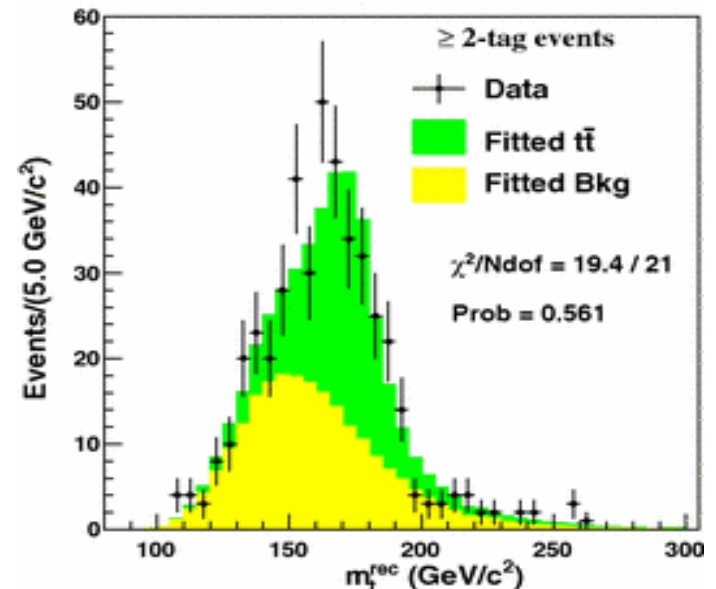
- smallest branching fraction (4%) and low backgrounds
- At least 1 b-tagged jet has 91% purity



$7.21 \pm 1.28 \text{ pb}$ 2900 pb^{-1}
CDF PRD 81, 052011 (2010)

All-jets

- biggest branching fraction (46%) and large backgrounds
- Jet model dominates systematics

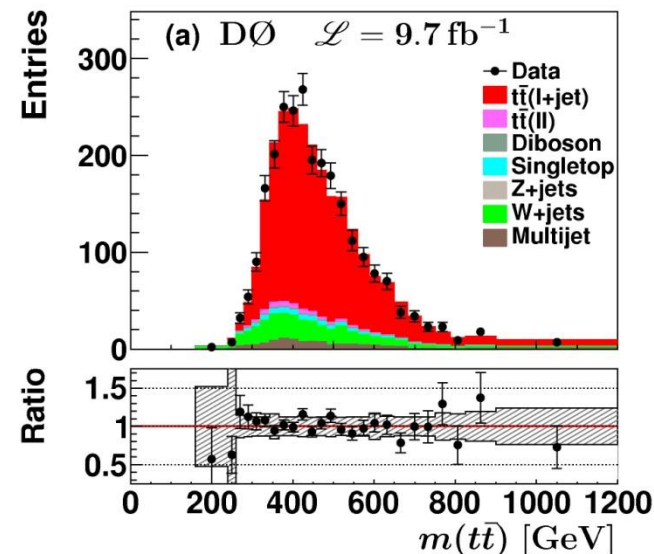


Differential cross section

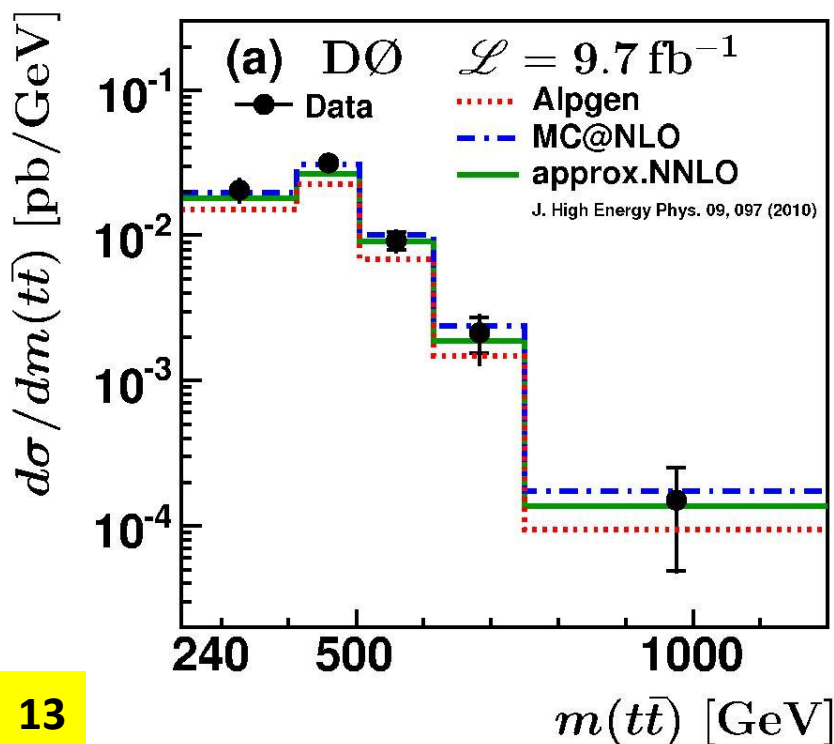
D0 Run II for lepton+jets 9700 pb^{-1}

Test model by Alpgen, MC@NLO and NNLO calculations

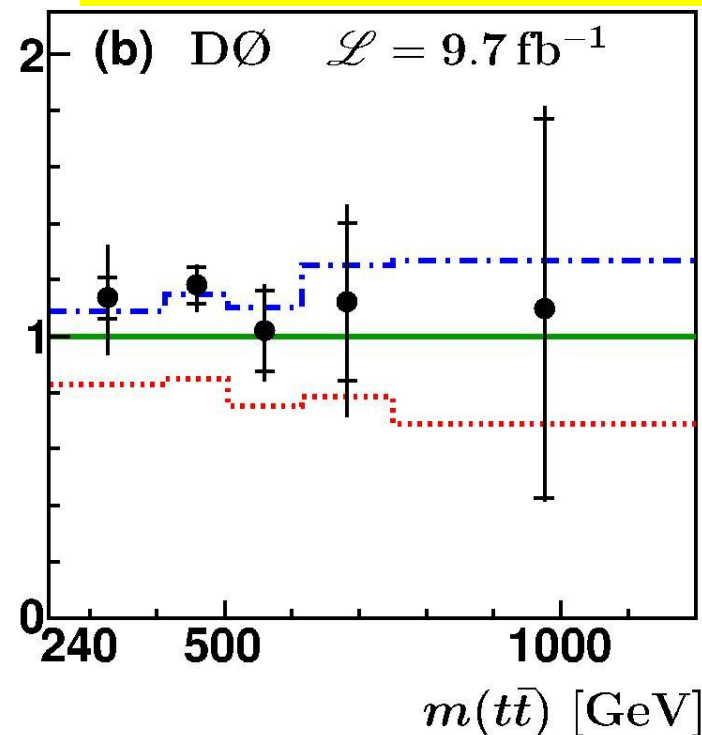
- low acceptance effects (central events)
- good agreement with standard model



D0 PRD 90, 092006 (2014)



Ratio to approx. NNLO

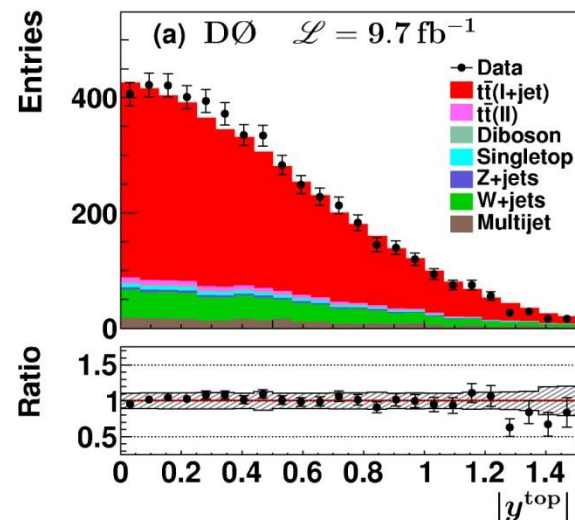


Differential cross section

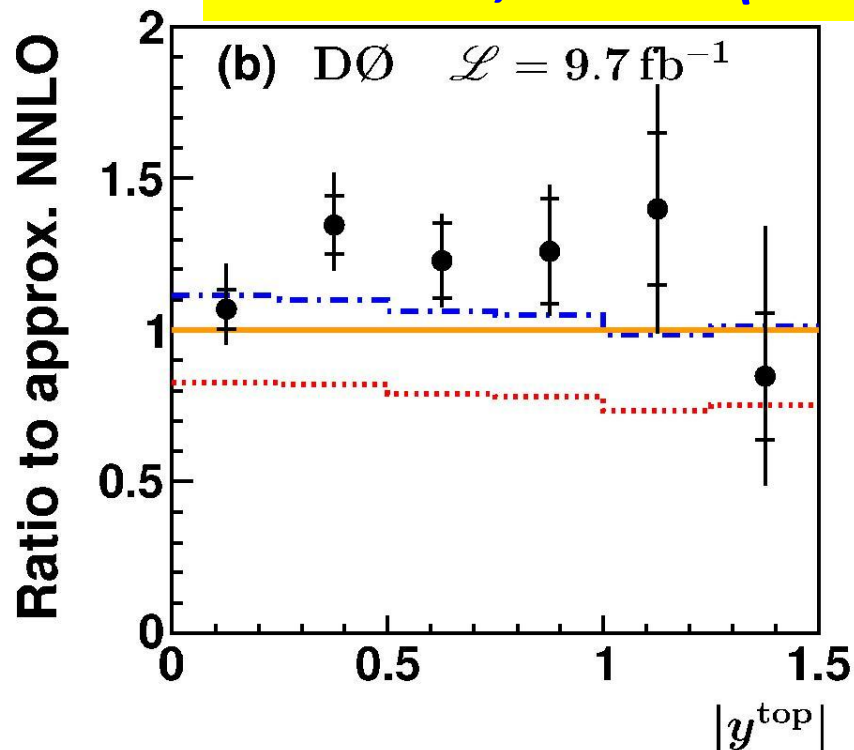
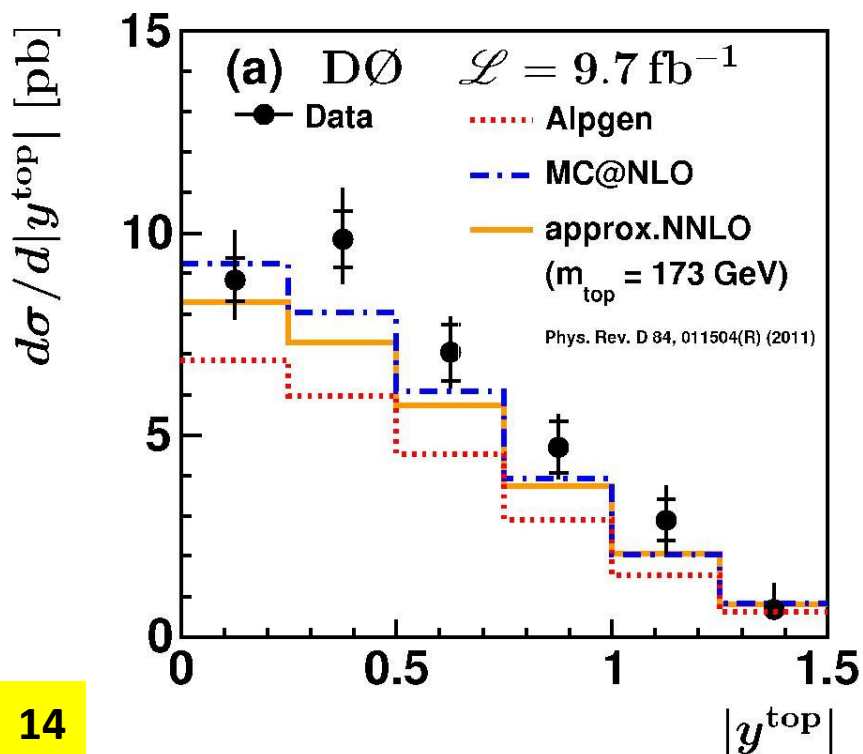
D0 Run II for lepton+jets 9700 pb⁻¹

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D0 PRD 90, 092006 (2014)

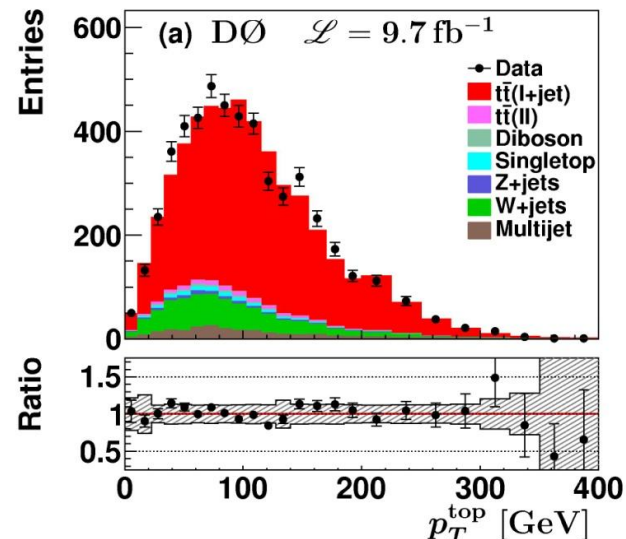


Differential cross section

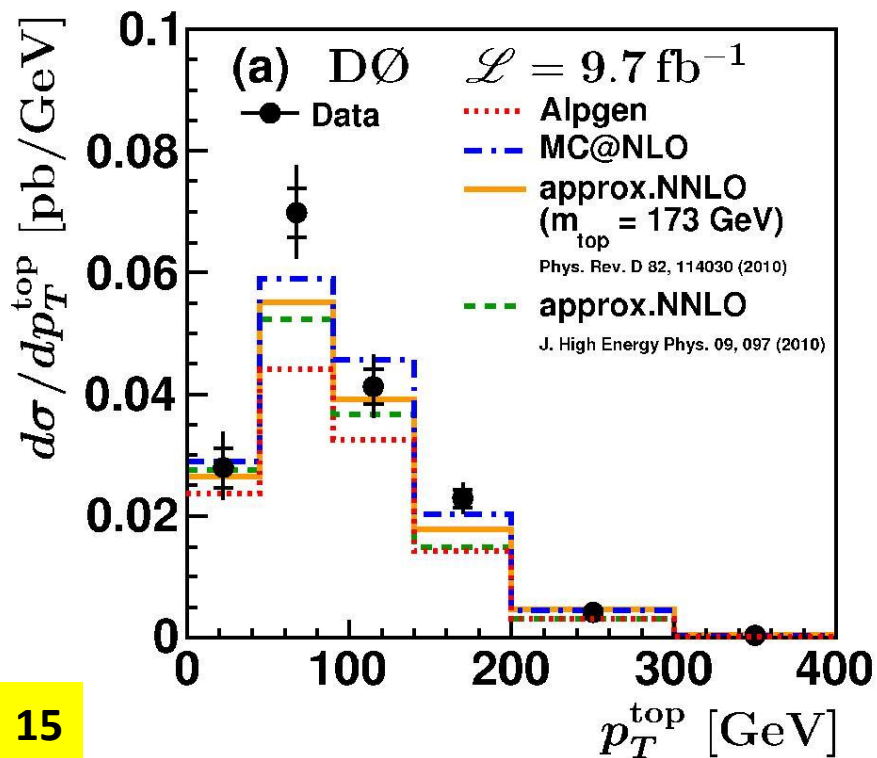
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D0 PRD 90, 092006 (2014)



Summary

- ✓ Different experimental final states in good agreement with each other
- ✓ Inclusive cross section in good agreement with impressive theoretical predictions
- ✓ Differential cross section with full Run II dataset tests QCD model

